TIME-DEPENDENT STRATIFIED FLOW OVER TOPOGRAPHY: WAVES AND ROTATING HYDRAULICS

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LONG TERM GOALS

The long term goals of this research are understand the interaction of stratified flow with topography with an emphasis on flows relevant to coastal oceans and marginal seas.

OBJECTIVES

The specific objectives of this last year and the coming year are two-fold. The first is a study of time-dependent adjustment in rotating strait and sill flows. This work centers upon the mechanisms for establishment of hydraulically controlled flows (single layer at present) in a rotating channel. Also of interest are the dynamics of shocks, jumps and flow separations which are common in such flows. This builds upon the PI's previous work on time-dependent, non-rotating hydraulic exchange flows (Helfrich, 1995). The second objective is the study of long internal wave generation by tidal flow over topography (e.g. the continental shelf break). Specific issues to be addressed are the role of a shelf-break front in the generation process and internal wave generation and propagation in two horizontal directions (e.g. wave generation from a canyon).

APPROACH

This work is being carried out using theoretical and numerical modeling in conjunction with laboratory experiments. The work described below on hydraulics of rotating flows has been in collaboration with L. Pratt (WHOI) and A. Kuo (Columbia) in the dam-break problem and with L. Pratt and E. Chassignet (U. of Miami) on the extension of Long's problem to include rotation.

WORK COMPLETED

During this year the PI has developed a numerical model capable of accurately handling both shocks and flow separation (zero layer depth) in single and multi-layer two-dimensional (x-y) hydrostatic flow. It is based upon the conservative (momentum and mass) flux form of the equations of motion necessary for accurate shock capturing. The scheme has been thoroughly tested against analytical solutions where possible with very good results. The model has been used in the study of two rotating hydraulics problems: (1) a rotating version of the classic dam break problem in a uniform channel and (2) an extension to include rotation of Long's classic problem of establishment of hydraulically controlled flow and upstream influence in single layer flow over topography. Thus during last year (FY97) the focus has been on the first group of problems described above in the objectives. These problems provide stringent tests for the numerical model since some analytical solutions are available.

RESULTS

The classic dam break problem in a uniform width channel has been extended to include the effects of rotation. When the depth of the fluid is initially uniform upstream of the dam and zero downstream of it, the evolution of the flow can be obtained analytically by assuming geostrophic along-channel flow (semigeostrophy) using the characteristic method and simple wave theory. The nature of the flow is investigated as a function of the sole parameter in the problem, the width of the channel relative to a deformation radius based on the initial upstream fluid depth. The fluid intrudes as a narrow current along the right-hand wall with a constant nose speed, in excess of the nonrotating limit, that increases with channel width. Along the left-hand wall the flow separates from the boundary at a point that moves slowly downstream at a constant speed, which decreases as the width increases. Steady state solutions, including the mass transport, are found. Formal validity of the semigeostrophic approximation is expected for narrow channels; numerical computations of the full shallow water equations bear this idea out. Differences between the theory and computations increase as the channel width is increased and are due primarily to ageostrophic effects, including Poincare wave generation. The numerical work is being extended to consider initially finite, but different, depths on both sides of the dam. With large differences in the initial depths this is a nonlinear version of the Rossby adjustment problem. In this case the flow intrudes into the shallower region as a propagating shock. Flow separations from the left side wall may still occur. One interesting new result is that final steady state transport, suitably normalized, is given the nonrotating solution regardless of channel width.

Long's (1970) classic problem of establishment of hydraulic control and upstream influence has been extended to uniform rotating channels. Curves delineating regions in Froude number and obstacle height space of upstream influence have been constructed using the semigeostrophic approximation in the along-channel direction. Numerical solutions of the full single-layer shallow water equations in flux form have been undertaken to examine the temporal development of the flow when an obstacle is slowly introduced into an initially undisturbed flow of specific Froude number (suitably defined for this rotating problem) and channel width. For initially subcritical flows (typically not initially separated) upstream influence takes place by the propagation of a disturbance that eventually steepens into a shock. Downstream of the obstacle a slowly moving eddy (not accounted for in the theory) develops. When the initial flow is supercritical and separated from the left channel wall the upstream influence takes place via a very different mechanism. The incident flow bifurcates over the obstacle, some proceeding downstream and some crosses the channel to move back upstream as a separated boundary intrusion. Thus upstream of the topography there are different current streams, one moving downstream and another flowing upstream toward the originating basin. The bifurcation process may be of some interest for general coastal boundary current flows over topography.

IMPACT/APPLICATIONS

The work on hydraulics of rotating flows should, eventually, help in the understanding of strait flows and the role straits and sills play in regulating the flow between basins, marginal seas, etc.

TRANSITIONS

None yet.

REFERENCES

Helfrich, K. R. 1995. Time-dependent two-layer hydraulic exchange flows, *J. Phys. Oceano.*, **25**, 359-373.

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